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OPEN OCEAN DEMONSTRATION OF VERTICAL FLOAT SEA-STABILIZATION CONCEPT

PHASE II TESTS

JUNE 1964

CONVAIR

OPEN OCEAN DEMONSTRATION OF VERTICAL FLOAT SEA-STABILIZATION CONCEPT

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Our sincere thanks are also given to the Bureau of Naval Weapons Representative at San Diego for expeditious coordination of all local Navy support.

The task of assembly of the vertical floats to the test seaplane was most efficiently handled by the Navy Supply Department at the Naval Air Station, North Island.

Credit is also due the officers and men of the ATA KOKA and YTB MUSKEGON for towing services provided during the testing period, and to the Naval Air Station, North Island, Boat Division for assistance in handling and mooring the two vehicles.

Without the timely support of the above named organizations, the test program could not have been completed within the limited time and budget allotted.

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SUMMARY AND CONCLUSIONS

Open sea testing of the PBM vertical float sea stabilization system has been successfully completed under Sea State 4 conditions. The 1964 tests were not only accomplished in larger waves, but with heavier gross weights and with lower operating heights from the water than previous tests conducted in 1963.

Earlier reports have detailed the effects of installing vertical floats on the PBM dynamic model and full-scale seaplane in minimizing wave induced motions. All testing to date has dramatically demonstrated the effectiveness of vertical floats in creating a stable platform in waves. Full-scale experiments have now been completed successfully in waves up to 10 feet in height and in winds up to 30 knots, with no major problems.

The latest series of open sea tests have further verified the habitability of the stabilized platform in waves. In 1964, the crew aboard the conventional seaplane hull suffered extreme discomfort and motion sickness, contrary to the stable and comfortable ride experienced by the crew aboard the vertical float equipped vehicle. The 1964 vertical float tests resulted in the following conclusions:

a. Properly designed vertical floats on a PBM seaplane will eliminate most of the pitching, rolling, and heaving motions normally experienced in Sea States 1 through 4. For example, the maximum pitch amplitude recorded for the conventional hull was 13.5 degrees, while the maximum pitch amplitude for the vertical float seaplane during the same time period was only 2.0 degrees.

b. The addition of vertical floats to a PBM-type seaplane did eliminate motion sickness and general crew discomfort while operating in Sea States 1 through 4.

c. No adverse effects from waves occurred when the vertical float seaplane keel height was reduced from 10 feet to 5 feet above the mean water surface, during Sea State 4 conditions.

d. Increasing the gross weight of the vertical float seaplane from 45,700 pounds to 60,000 pounds did increase the stability in waves.

e. The intensity of underwater sound measured by hydrophones suspended in the water below each vehicle was considerably less in the case of the vertical float seaplane.

f. The drift rate due to winds for the vertical float seaplane was less than that for the conventional seaplane in higher winds (20 to 30 knots) but approached equality in winds below 15 knots.

g. Towing the PBM vertical float seaplane did not present any special problems unless winds exceeded 20 knots and came from the seaplane beam. Higher beam winds required addition of a small amount of water ballast to the upwind vertical float to maintain a wing-level altitude. Towing directly into higher winds did not noticeably affect the seaplane trim angle.

The knowledge gained through this program has further substantiated the feasibility of creating a seaplane that can operate as a stable platform on the surface of the open ocean in up to Sea State 4 conditions. Based on results from the 1963 and 1964 open sea tests, there are strong convictions that this vertical float installation could operate satisfactorily under Sea State 5 conditions.

INTRODUCTION

The future ASW weapon system will require the use of a true open-ocean seaplane, both as a fast, sensor bearing vehicle and as a weapon carrier-launcher. Historically, the conventional seaplane has been ill suited for operations on the rough waters normally encountered in the open sea, not only because of hull structural limitations but because of the r pid deterioration of crew performance as the seaplane pitches and rolls on the ocean surface.

To take advantage of its superior speed, range, and load carrying ability, the seaplane must be designed to better utilize the ocean surface. Not only must the aircraft be able to take off and land in the open ocean but, for the crew to operate sensors and weapons effectively, it must provide a stable platform while resting on the surface. The purpose of the work to date has been to investigate the solution of this problem — that is, the attainment of a stable platform at sea.

The vc tical float sea stabilization concept was conceived by Mr. E. H. Handler of the Bureau of Naval Weapons. Vertical floats support the weight of the entire vehicle and, through use of damping structures and reduced waterplane areas, minimize pitching, rolling, and heaving motions due to waves. This concept makes possible, for the first time, a method of stabilizing seaplanes at sea and allowing sustained station eping.

Convair has demonstrated the effectiveness of the vertical float concept under previous contracts with the Bureau of Naval Weapons — with both models and full-scale testing.

The first model testing was completed in mid-1962, using a 1/20-scale dynamic model of the PBM seaplane. The tests were conducted in the Convair towing basin. Their results were highly encouraging.

Early in 1963, Convair started work on the modification of two surplus Navy-furnished PBM-5 seaplanes for a full-scale program. The first full-scale test took place at San Clemente Island, off southern California, in April and May 1963. Because of unavoidable delays, the expected Sea State 4 conditions were not obtained at San Clemente. However, operations in Sea State 3 conditions gave full-scale substantiation of the vertical float concept.

Additional tests were undertaken in 1964. The San Diego area was selected as the site for the follow-on test program to simplify the assembly, maintenance, and support of the two test vehicles.

The 1964 open-sea test program was conducted between 10 March and 15 May. The tests were discontinued after 15 May because of the reduced probability of high sea states.

This report deals primarily with the 1964 test program, although some reference is made to earlier tests for comparison.

1 TEST EQUIPMENT

Testing for the 1964 full-scale vertical float program was conducted with the two Navy-furnished PBM-5 seaplanes used in the 1963 program. The seaplane engines were preserved and not used in the tests. Both aircraft had been cannibalized to the extent that they were no longer airworthy.

Electrical power for the instrumentation and lights was supplied by the regular aircraft auxiliary-power unit. In addition to the aircraft system, the vertical float seaplane carried a 6-kva, 60-cyle auxiliary-power unit to supply 115-volt alternating current for the float pumps.

The vertical floats and struts were made of MIL-A-19070 5086H aluminum alloy. This material was chosen for its high corrosion resistance to salt water and its weldability. The parts were fabricated from curved 1/4-inch plate. At stress concentrations, such as float pivot fittings, 75T6 alloy was used. Cables, shackles, and turnbuckles were hot-dipped galvanized steel.

The vertical floats were pin connected to the aircraft by use of a limited universal joint. Cable ends and struts were attached with single-pin fittings to facilitate assembly. None of the hardware developed any corrosion problems, even after long exposure to salt water. A three-view drawing of the vertical float seaplane is shown in Figure 1.

Both seaplanes were equipped with Convair-built photopanels containing the instrumentation for recording changes in pitch, roll, vertical acceleration, lateral acceleration, and longitudinal acceleration.

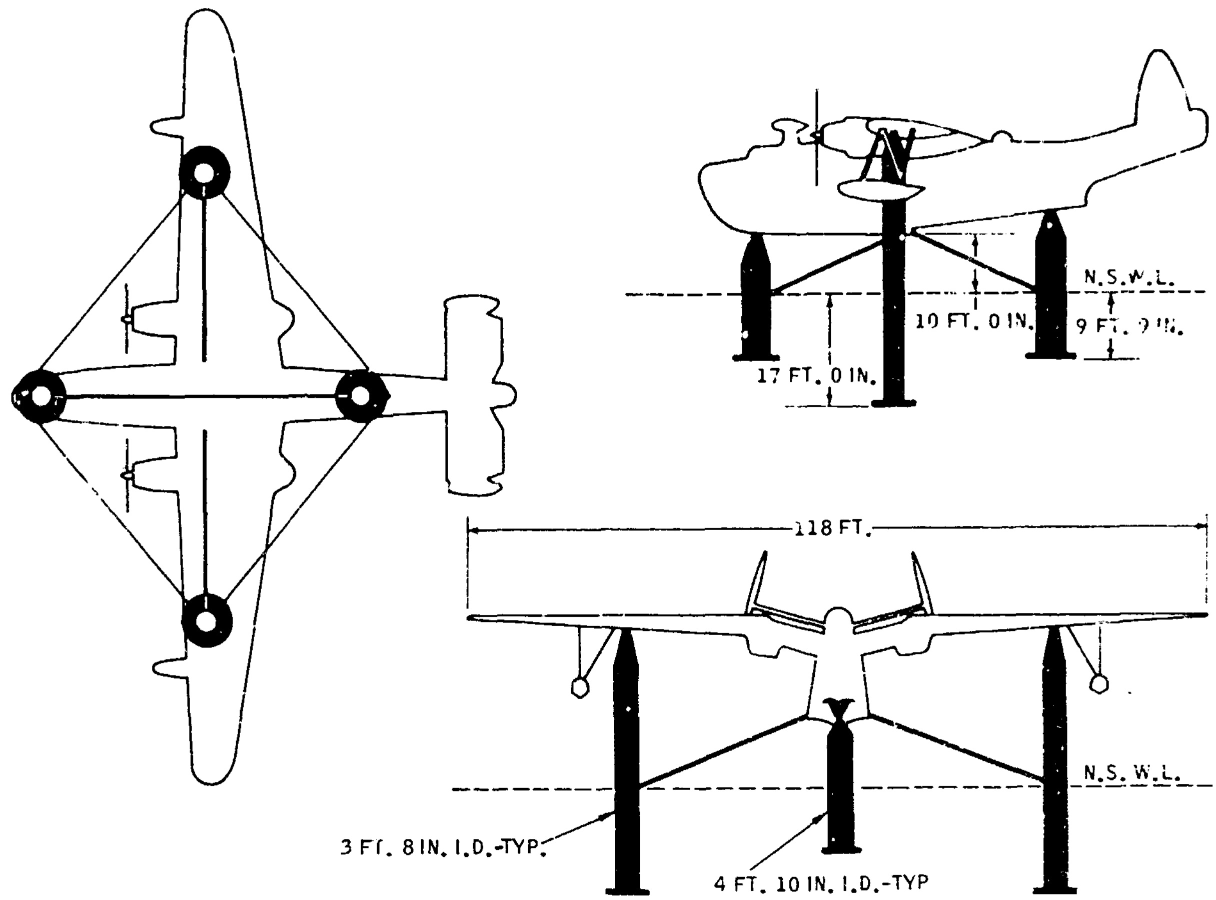


Figure 1. Vertical Float Installation — Principal Dimensions

The vertical float seaplane also contained strain-gage instrumentation on the bow, stern, and port-wing vertical floats to measure changes in loads transmitted from waves to the aircraft at the float attachment points. The struts and cables attached to these floats were also instrumented to measure loads in the float attachment structure.

Photopanel filming was done using 35-mm black-and white film. Filming was done concurrently in both seaplanes to give valid time comparisons. Because the time at sea during each test was usually 7 or 8 hours, the photopanel was actually filmed only for selected short intervals. Typical 2-minute portions of the data recorded on film have been plotted and appear in Chapter 3. The large bulk of recorded data is stored on several hundred feet of 35-mm black-and-white film.

Additional coverage was provided by 35-mm cameras mounted inside the vertical float seaplane hull. These cameras operated simultaneously with the photopanel camera, recording pictures of waves as they passed the port-wing and aft-fuselage vertical floats.

In addition to the 35-mm camera coverage on each plane, colored motion pictures were made during each open-sea test. This film is considered part of the report. The movie coverage includes views from the vertical float seaplane, the towing vessel, and a helicopter.

Semiconductor strain gages were used on the floats and struts, and standard foil gages were used on the cables. The semiconductor gages had a sensitivity of 162, compared with the standard-gage factor of 2.0. A full Wheatstone bridge circuit was used in each case, with the gages oriented and interconnected to cancel output due to side-loading and temperature changes. High-resistance (1,000-ohm) semiconductor gages were used with low applied voltage to avoid self-heating effects. The completed installations provided a stable bridge balance with 5 volts applied.

To investigate the relative intensity of underwater noises in the vicinity of the two seaplane configurations, two AN/SSQ-28 sonobuoy hydrophones were suspended under each hull. The sonobuoys were activated during each test and tape recordings made of the sonobuoy output for analysis. The tape recording is also considered to be a part of the report.

2 TEST PROCEDURES AND OPERATIONS

These tests were conducted 4 to 6 n.mi. west of San Diego harbor in water varying in depth from 200 to 300 feet.

The difficulty of supporting the operations at San Clemente Island in 1963 was the main reason for moving to San Diego. Not only were support problems simplified, but the vertical floats were assembled at great savings to the Navy by using the large crane and skilled riggers at North Island NAS.

Rigging was completed 20 February, and the test airplane was towed to a mooring in the ocean off North Island on 24 February. The vertical floats were damaged during the tow, to the point that repairs were required. The repairs were completed by 18 March and the seaplane was again ready for sea.

2.1 TEST PROCEDURES

Both test seaplanes were manned by Convair crews that monitored the instrumentation and acted as observers during the tests. A typical test day started at 0600, when the seaplanes were picked up by tugs and towed to the open sea (Figure 2). At towing speeds between 2 and 4 knots, several hours were required to reach the test area.

Once on station, the towlines were slacked so that the two test vehicles could drift freely (Figure 3). Instrumentation was activated on both seaplanes as they drifted, recording data simultaneously. The photopanel cameras were activated for 10-minute intervals.

As in the tests at San Clemente, the vertical float seaplane went to sea at a gross weight of 45,700 pounds (Figure 4), and the conventional seaplane was water ballasted to about the same weight. During part of the open-sea test, the weight of the vertical float vehicle was increased to 60,000 pounds by adding water ballast to each vertical float (Figure 5), and data was recorded at the heavier weight. For safety reasons, it was not considered advisable to further increase the weight of the conventional seaplane.

Sonobuoys were lowered during the drifting phase of the operation, and the underwater noise under each hull was tape recorded. Measurements were taken 90 feet beneath the surface under the conventional seaplane and 80 feet beneath the surface under the vertical float seaplane. The auxiliary-power units on both seaplanes were operated during the underwater-noise experiments.

2.2 TEST OPERATIONS

No rough seas were predicted in the San Diego area from 18 March to 1 April, when Fleet Weather Central predicted high sea states and strong winds in the area for the next two days. Accordingly, preparations were made for testing both seaplanes on 2 April.

It became apparent during the towing operation that conditions at sea were too severe for the initial test, and would exceed the limits for safe operation of the conventional seaplane. The test was therefore cancelled and the planes returned to their moorings in the habor.

Later in the day, it was learned that 40-knot winds and Sea State 6 conditions prevailed outside the harbor.

There was ample opportunity during the towing to observe the behavior of the vertical float seaplane in a 20 to 30-knot crosswind. With no corrective action applied, the crosswind lifted the upwind vertical float 6 feet out of the

Figure 2. Vertical Float Seaplane Under Tow

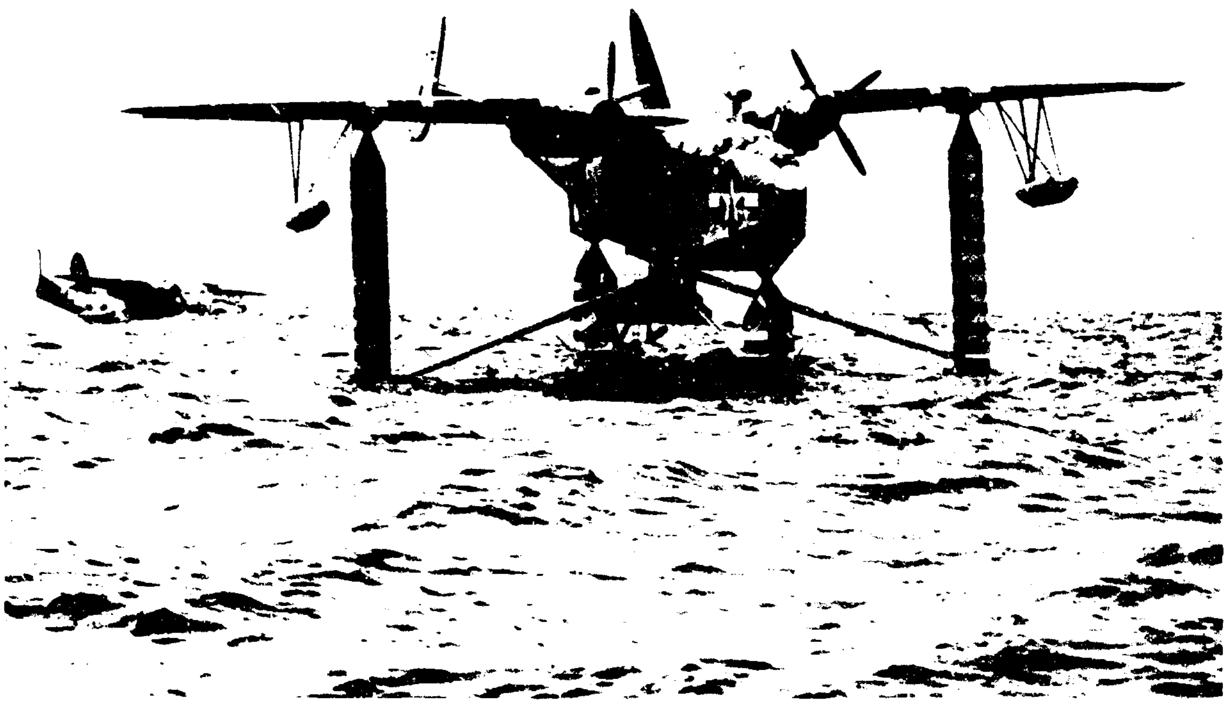


Figure 3. Both Seaplanes in Sea State 4 Waves

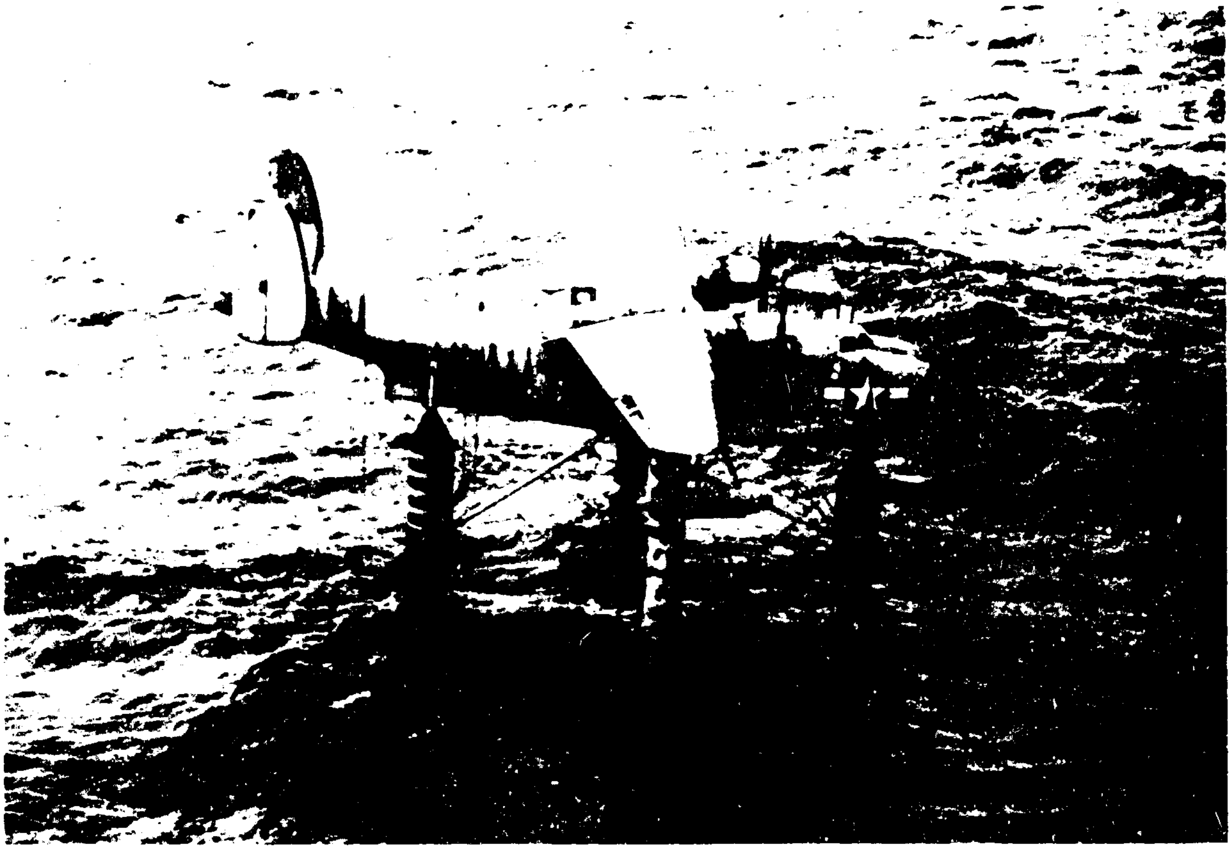


Figure 4. Vertical Float Seaplane at Sea

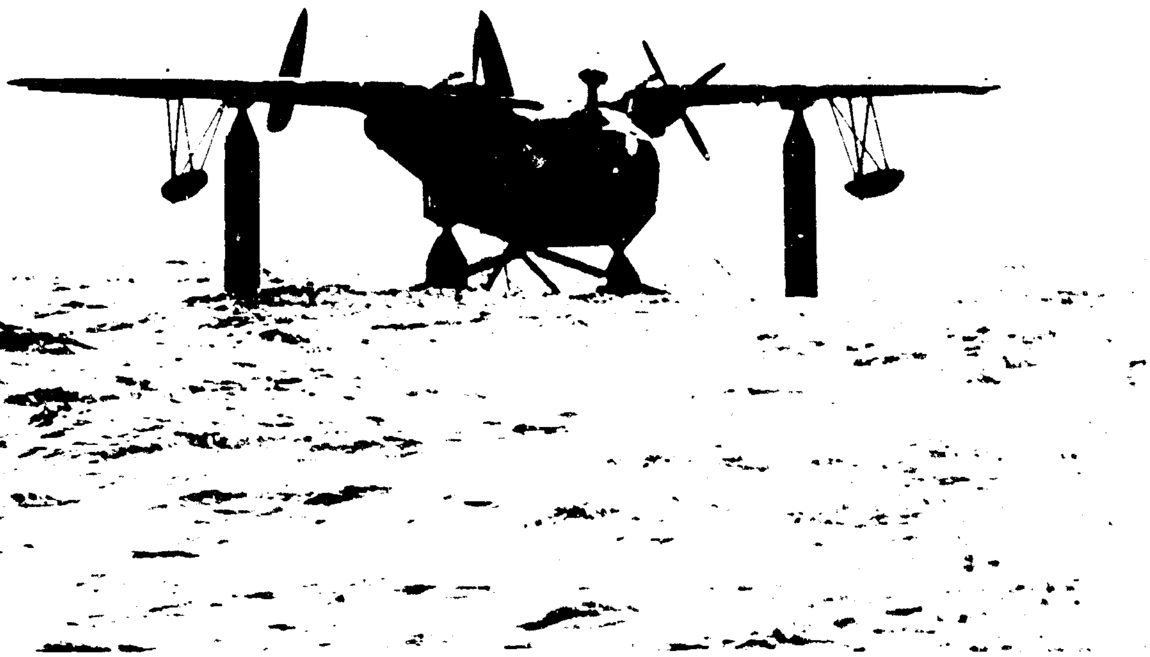


Figure 5. Vertical Float Seaplane at 60,000-lb. Gross Weight

water. While the plane was headed into the wind, or quartering, there were no adverse effects. From this demonstration, it was learned that severe crosswinds can be controlled by partially flooding the upwind float.

An open-sea test was scheduled again for 23 April. Fleet Weather Central forecast 5 to 7-foot waves and winds to 30 knots in the San Diego area.

The two test airplanes reached the open sea by 0800 and encountered 3 to 4-foot waves and 12 to 14-knot winds. By 1015 the wind had increased to 22 to 25 knots and waves reached heights of 6 to 7 feet, with numerous whitecaps and breaking waves. At 1100 the towlines were slacked and the instrumentation was activated in both seaplanes. By this time the wind had decreased to 15 knots and the whitecaps largely disappeared, although the waves continued to increase until occasional 8 and 10-foot swells were seen passing the seaplanes. Testing continued at intervals until 1500, when the return tow was started.

Open-sea operations were also conducted on 6 May, after Fleet Weather Central forecast another opportunity for Sea State 4 waves in the San Diego area. Although the winds failed to go over 15 knots, waves reached the 5 to 7-foot heights forecast. A series of successful tests were conducted, with results similar to those of 23 April.

Only the vertical float seaplane was used in the 6 May tests, satisfactory data on the conventional seaplane already having been collected.

The gross weight of the vertical float seaplane was varied during the drift phases, as was its height above the water. Throughout the test operations (at San Diego and at San Clemente), the seaplane showed very little tendency to alter its bow-on or quartering heading into the wind. Only when the airplane was towed directly crosswind did the effect of the wind become noticeable. The slight lifting of the upwind wing was easily offset by a small amount of water in the upwind-wing vertical float.

The airplanes at San Diego drifted at about 1.5 knots throughout the tests in 12 to 15-knot winds. This was in contrast to the experience at San Clemente, where the conventional seaplane hull drifted about twice as fast in slightly higher (average) winds.

3 | TEST RESULTS

The open-sea test program was completed in May 1964 with no unforeseen problems or failures in the vertical float system. As with the 1963 program, the problems encountered were related to operations, scheduling, and weather.

From 18 March through 30 May, only three periods of stormy weather occurred in the San Diego area, and one of them brought seas so rough that testing would have been dangerous. But with only two days suitable for test operations, the primary purposes of the 1964 test program were accomplished — earlier experiments were extended into higher sea states with greater gross weights.

Also completed were the planned investigations of underwater noise levels and effects of lower operating heights above the ocean surface.

These objectives were accomplished through a broad range of open-sea conditions. Figure 6 outlines the sea conditions (Reference 1) encountered during the 1963-1964 tests. As indicated by the shaded area, the vertical float seaplane has now been tested in Sea State 4 and in a variety of lesser conditions.

Most of the seas experienced were short-wave-length, local-wind-generated waves, instead of long-period swells from far out in the Pacific Ocean. One opportunity to observe long-period (8 to 10-second) swells was presented while the vertical float seaplane was moored in the ocean outside the harbor. As expected, the long swells caused only gentle heaving, with almost no pitching or rolling. This was probably due to the high L/H ratio (50) of the swells and their

relatively broad crests with respect to the distance between the vertical floats. This would indicate that sea stabilization efforts for the future ASW vehicle should center on reducing motions from steep, short-crested waves instead of long-wave-length swells.

Since the crews were exposed to the confinement and motion of the seaplanes for relatively long times (12 to 15 hours), a basis was provided for comparing discomfort and motion sickness. No motion sickness was reported (or observed) on the vertical float seaplane, but both members of the crew on the conventional PBM reported extreme discomfort and seasickness in the open sea.

From the human-factor standpoint, the allowable amplitude of motions cannot be defined precisely, as individual tolerances differ considerably; however, experience in ships and boats exposed to different wave conditions has established some general upper limits to tolerable motion. Angular motions of 10 degrees per second, for example, have been described as very uncomfortable, and motions below 4 degrees per second have been described as comfortable (Reference 2).

Test observations and data presented in Figures 7, 8, and 9 show that the pitch and roll variations in the conventional-hull seaplane exceed these limits.

Rapid changes in acceleration also produce disturbing effects on some crew members. Variations in the vertical, lateral, and longitudinal accelerations of the two seaplanes are compared in Figures 10, 11, and 12.

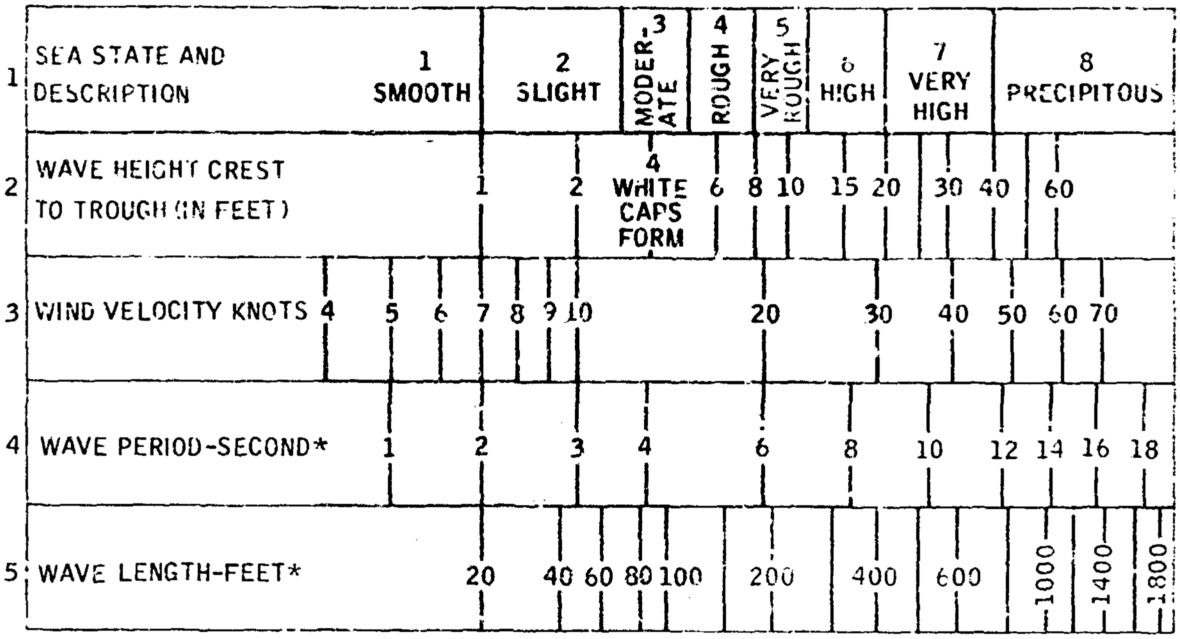
The vertical float seaplane was lowered closer to the surface of the ocean in two stages. First, by increasing the gross weight to 60,000 pounds, the seaplane was lowered to an operating height 6 feet above the ocean. During that time, no waves were seen striking the hull. Later, the operating height was reduced to about 4 feet above the water with no adverse effects. As shown in Figures 7 and 8, the increase in weight slightly increased the stability of the

seaplane. This was expected, both from the effects of increased mass and the penetration of the vertical floats into the region of lesser particle velocity.

Figure 13 shows waves passing the vertical floats at different gross weights.

A strain-gage system was activated at various times during the drift phase, and data was recorded from the photopanel. Typical plots of the load variations due to waves are shown in Figures 14A through D. The plots represent load changes above and below a calibrated zero point. Cable loads shown below the calibrated zero are still tension loads because of the cable rigging preload; loads in the vertical floats represent changes in compression; and loads in the struts are changes above or below the rigging preload. Strain-gage sensitivity to temperature change was negligible over the temperature ranges encountered. The sensitivity of the semiconductor gages changed 2 percent per degree Fahrenheit for the range experienced. The largest correction from the calibration temperature would be 0.5 percent. Detail drawings and calibration curves for the strain-gage system are included with other data furnished under the contract.

Underwater noises were recorded on tape during the drift phase of the operation. Plots of the playbacks from both vehicles are compared in Figure 15. All points on the curves are referenced to the 1,000-cps level from the conventional hull recording. The tape recording is submitted as part of the report.



CORRESPONDING VALUES LIE ON A VERTICAL LINE
*ONLY LINES 4 AND 5 ARE APPLICABLE TO SWELL AS WELL AS TO WAVES.

Figure 6. Wind and Waves at Sea

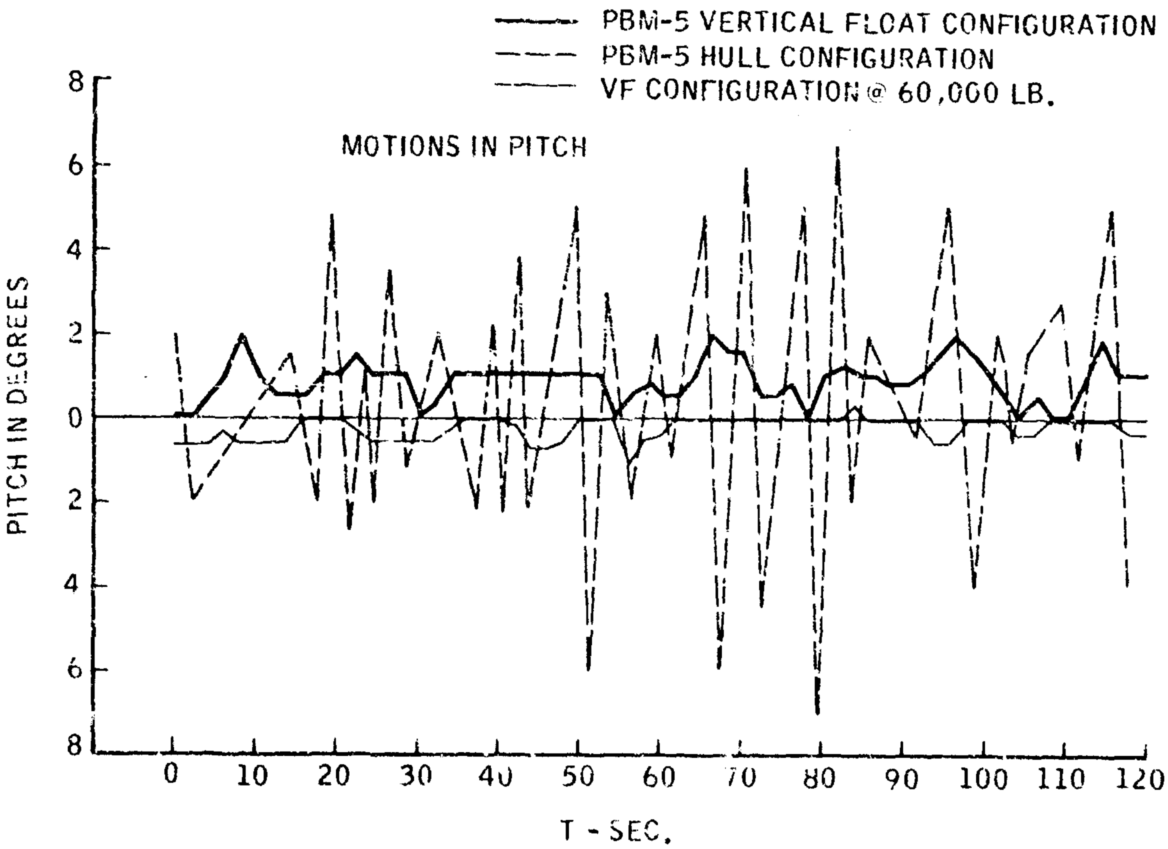


Figure 7. Comparison of Motions in Pitch

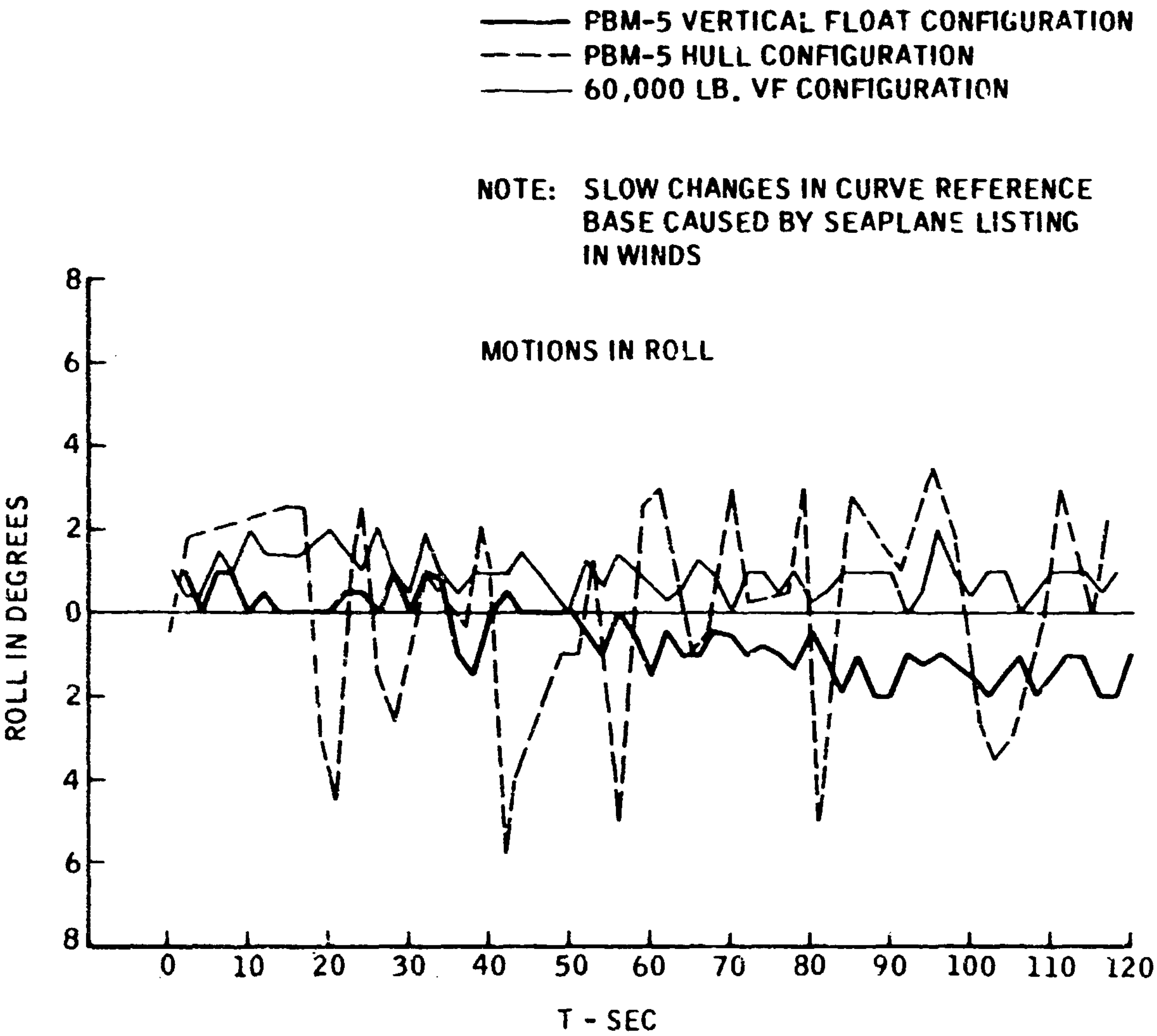


Figure 8. Comparison of Motions in Roll

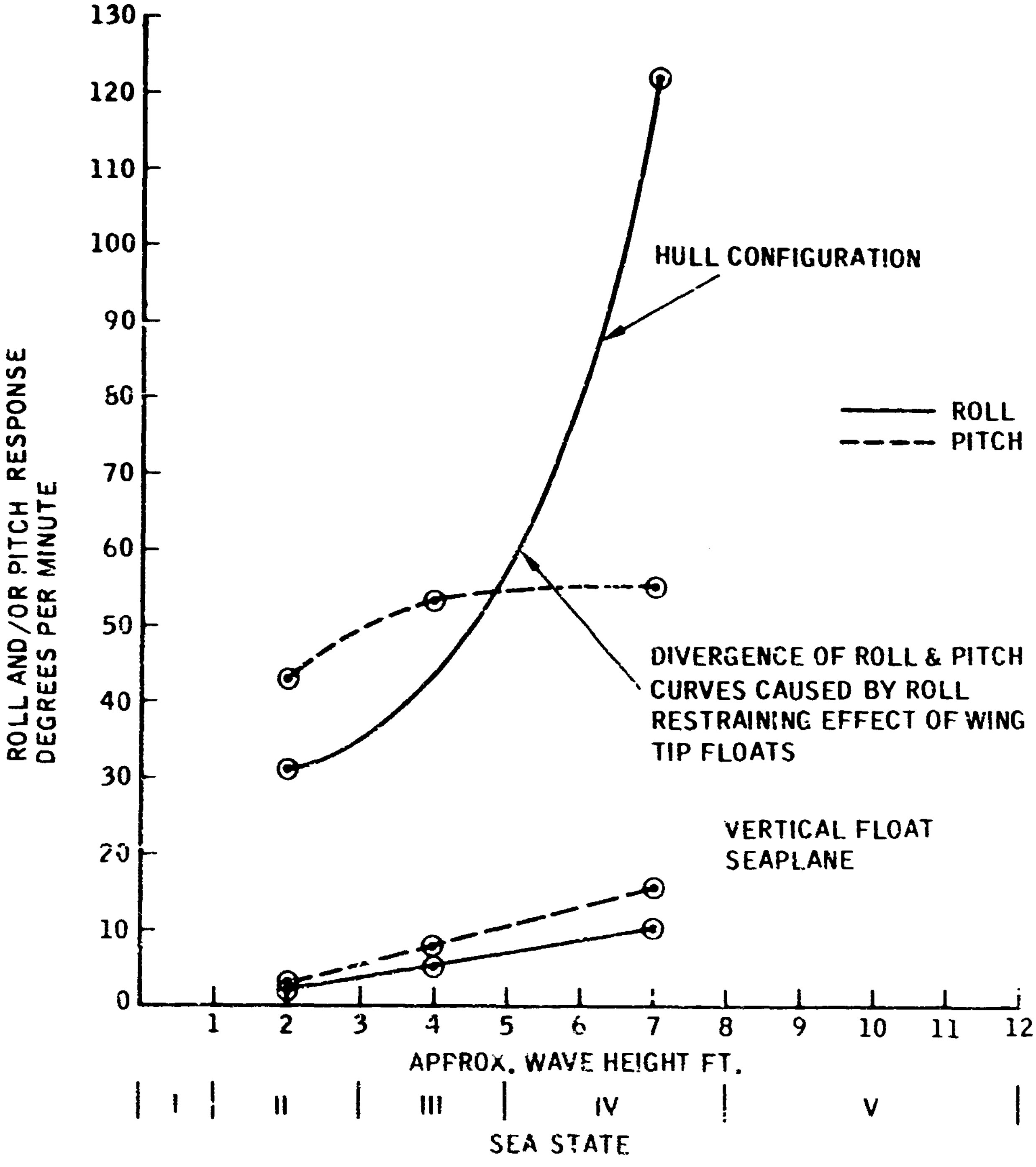


Figure 9. Roll and Pitch Response vs. Wave Height

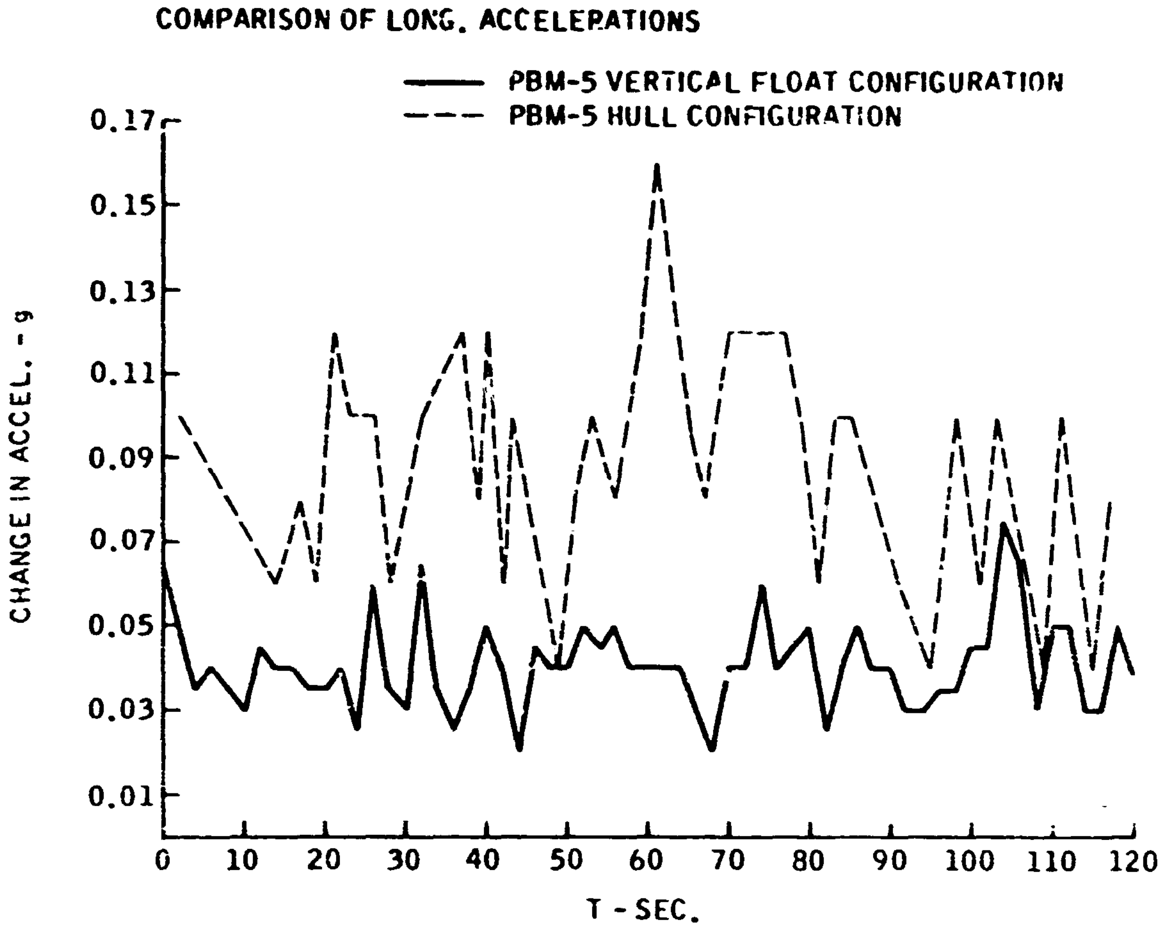


Figure 10. Comparison of Longitudinal Accelerations

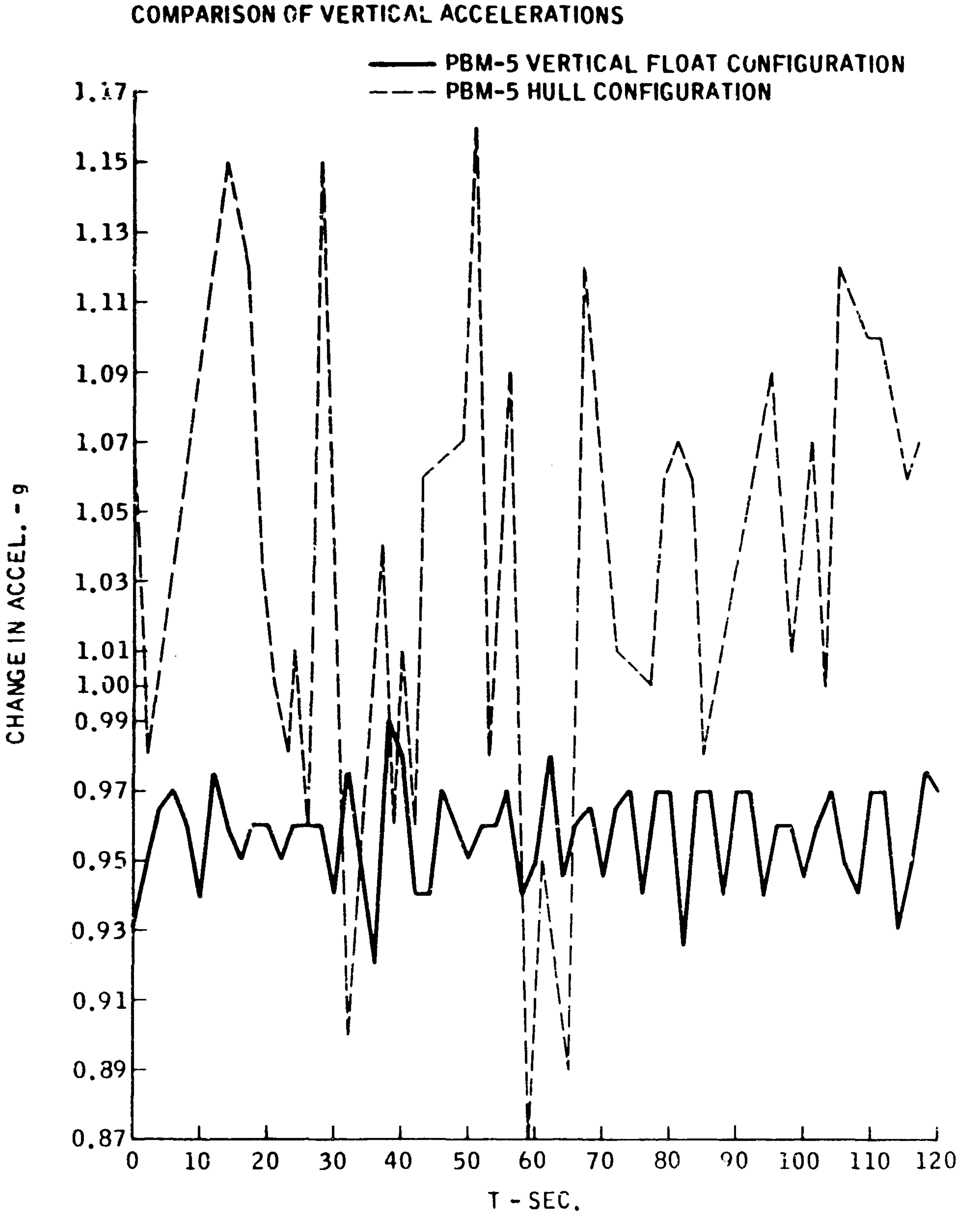


Figure 11. Comparison of Vertical Accelerations

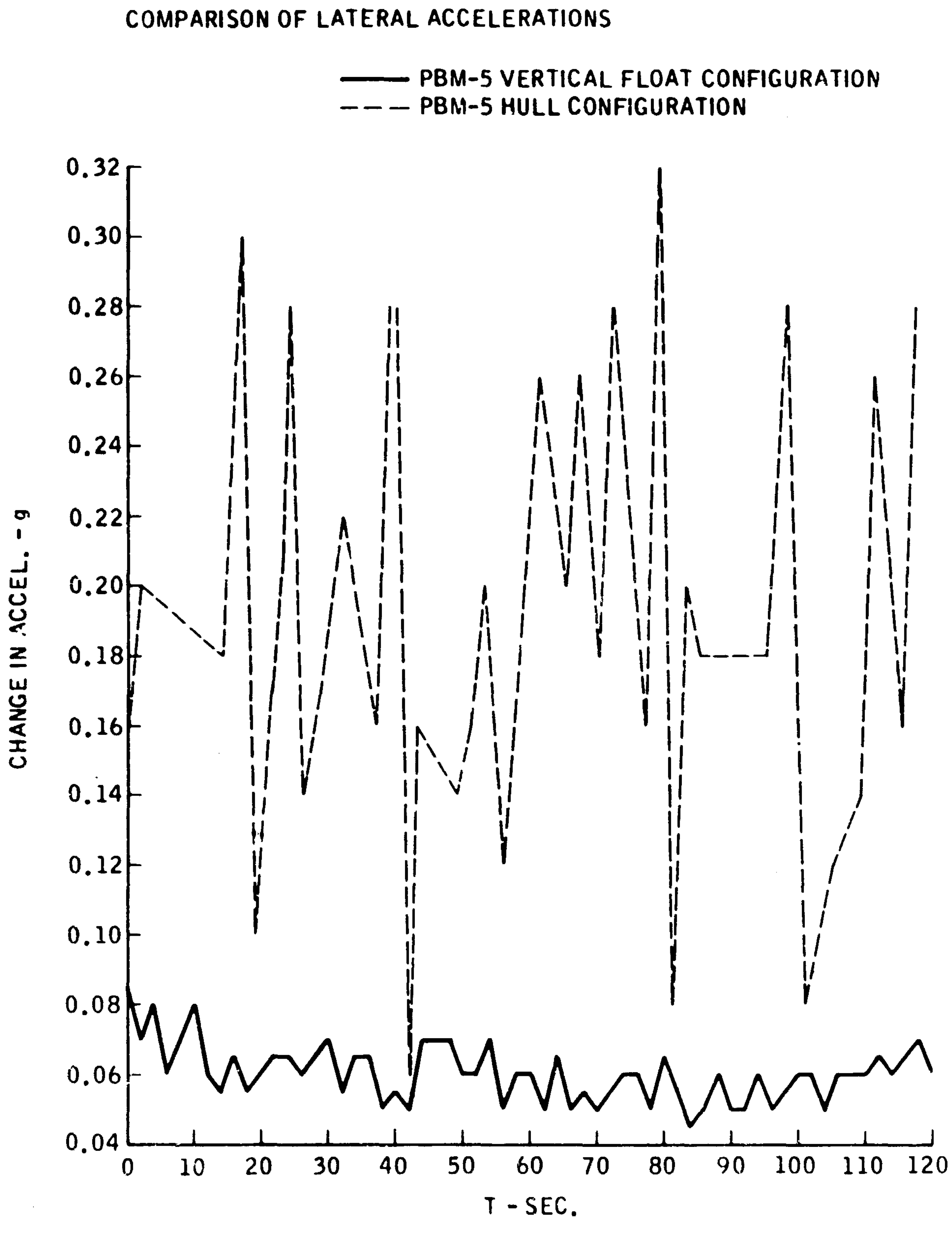
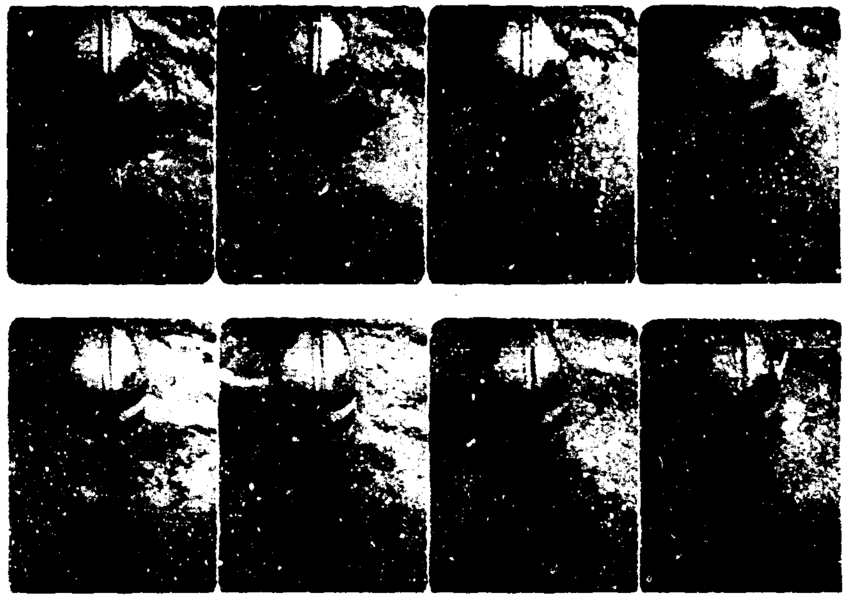
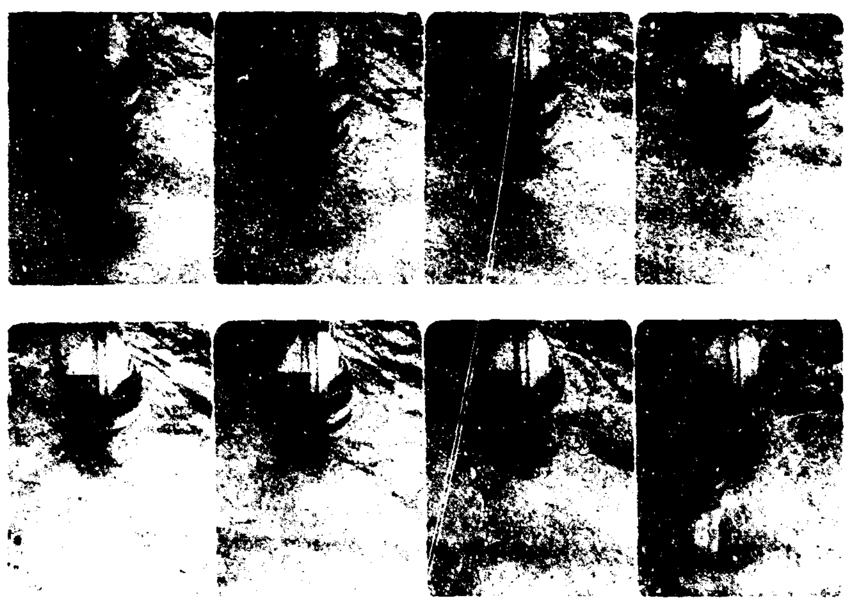


Figure 12. Comparison of Lateral Accelerations

Wing Float in
7-ft. Waves
at 45,700-lb.
Gross Weight



Aft Fuselage Float in 7-ft. Waves
at 45,700-lb. Gross Weight



Aft Fuselage Float in 5-ft. Waves
at 60,000-lb. Gross Weight

Figure 13. Vertical Floats at Different Gross Weights

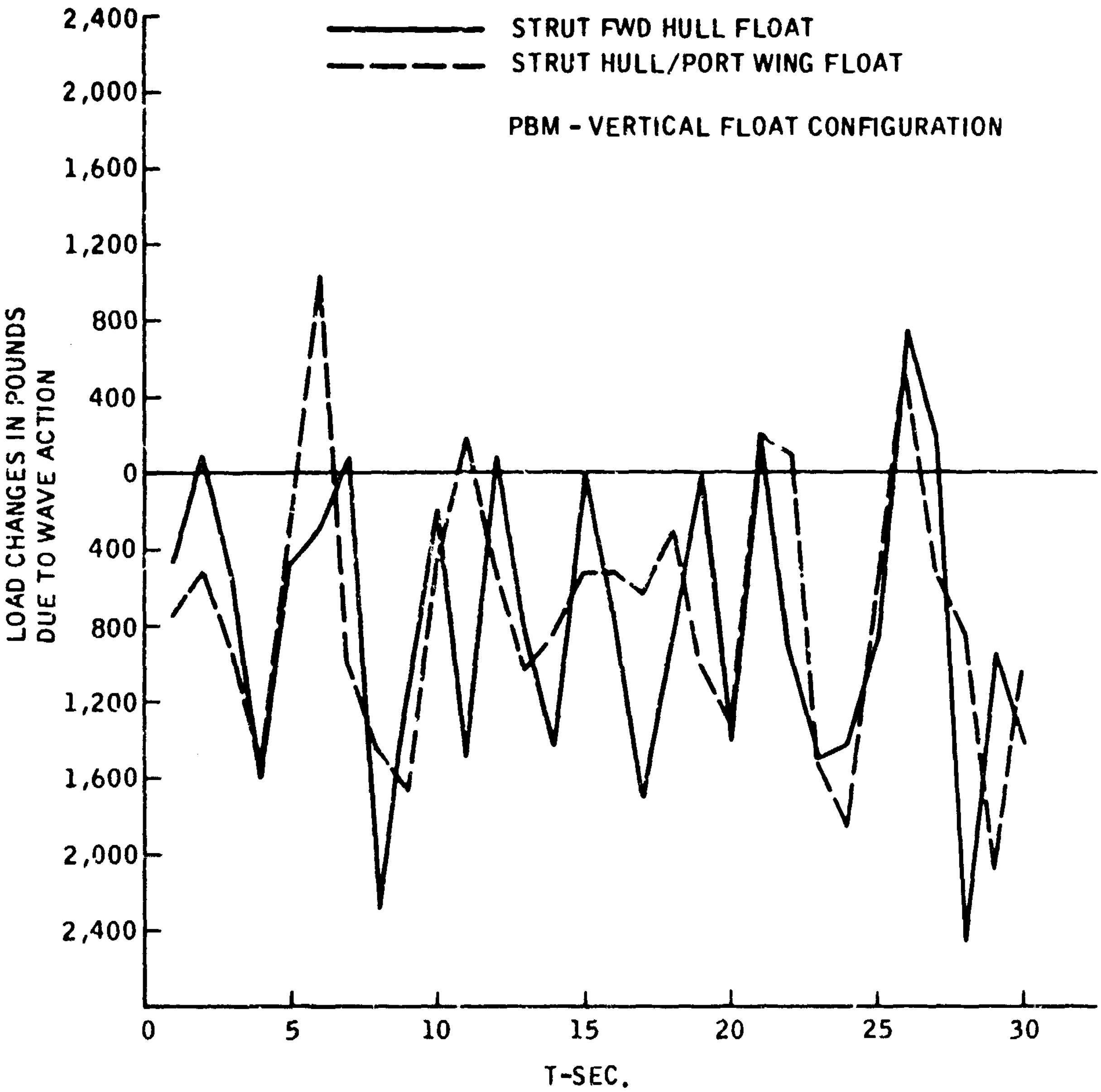


Figure 14A. Variations of Structural Loads Due to Waves

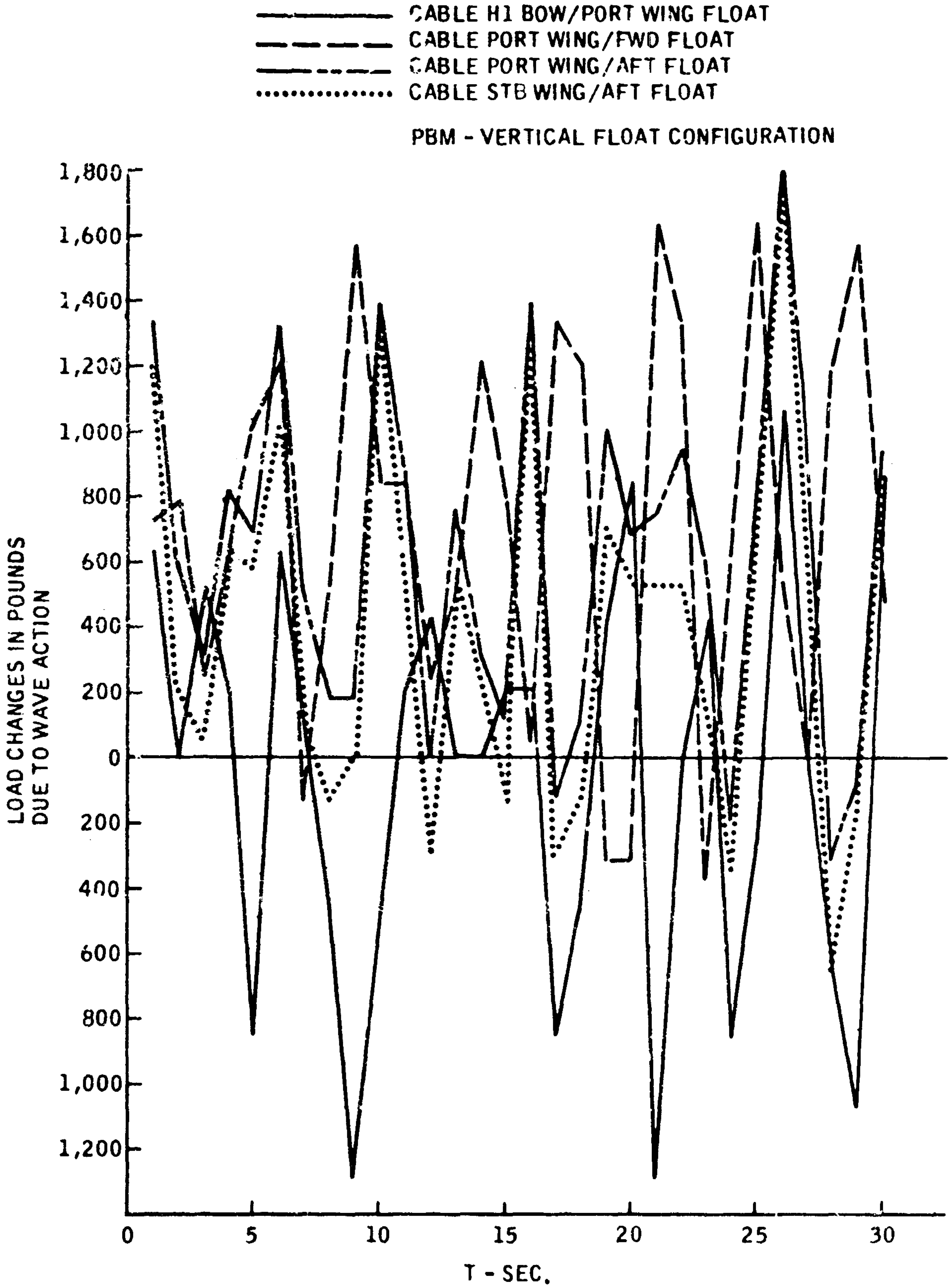


Figure 14B. Variations of Structural Loads Due to Waves

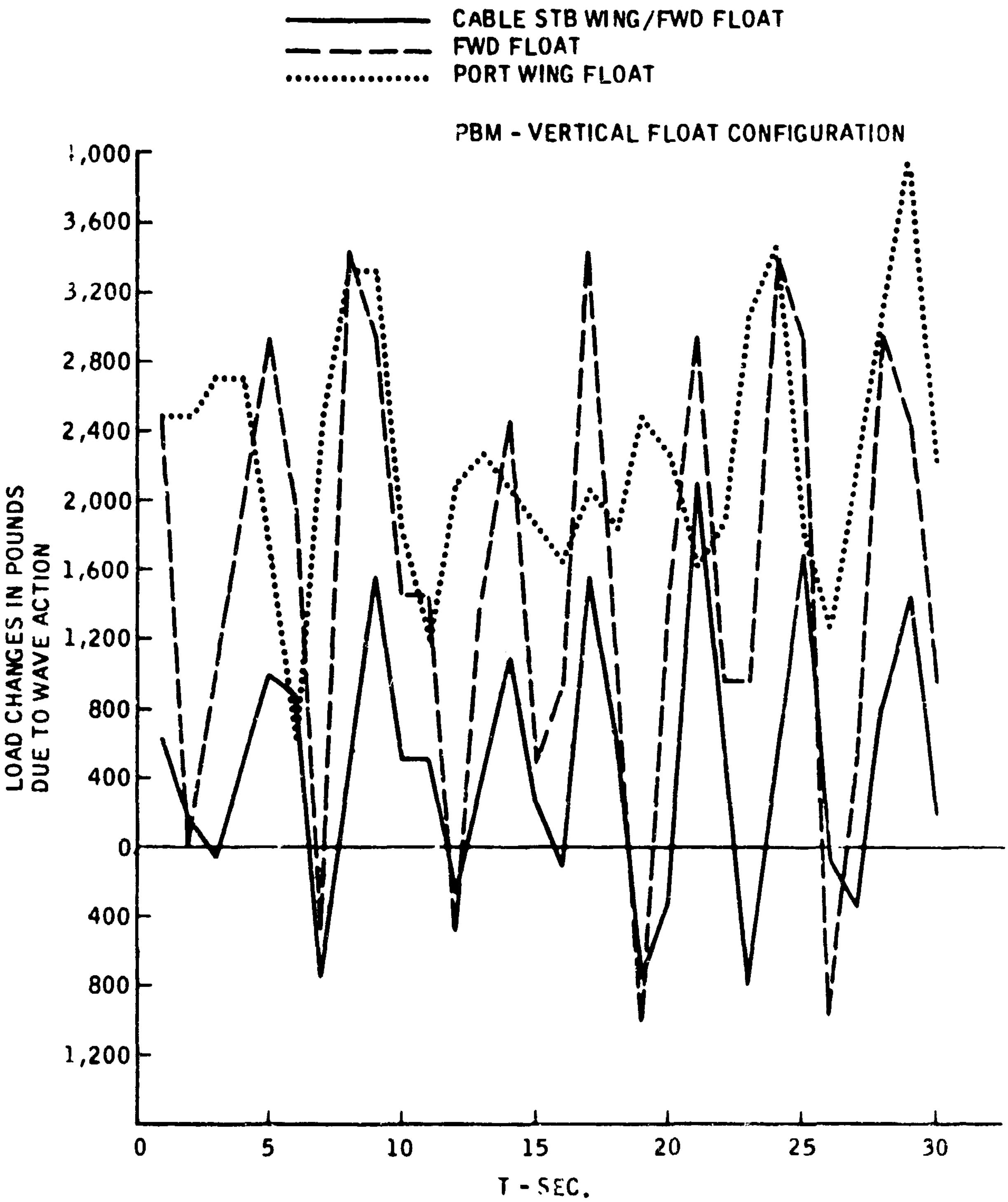


Figure 14C. Variations of Structural Loads Due to Waves

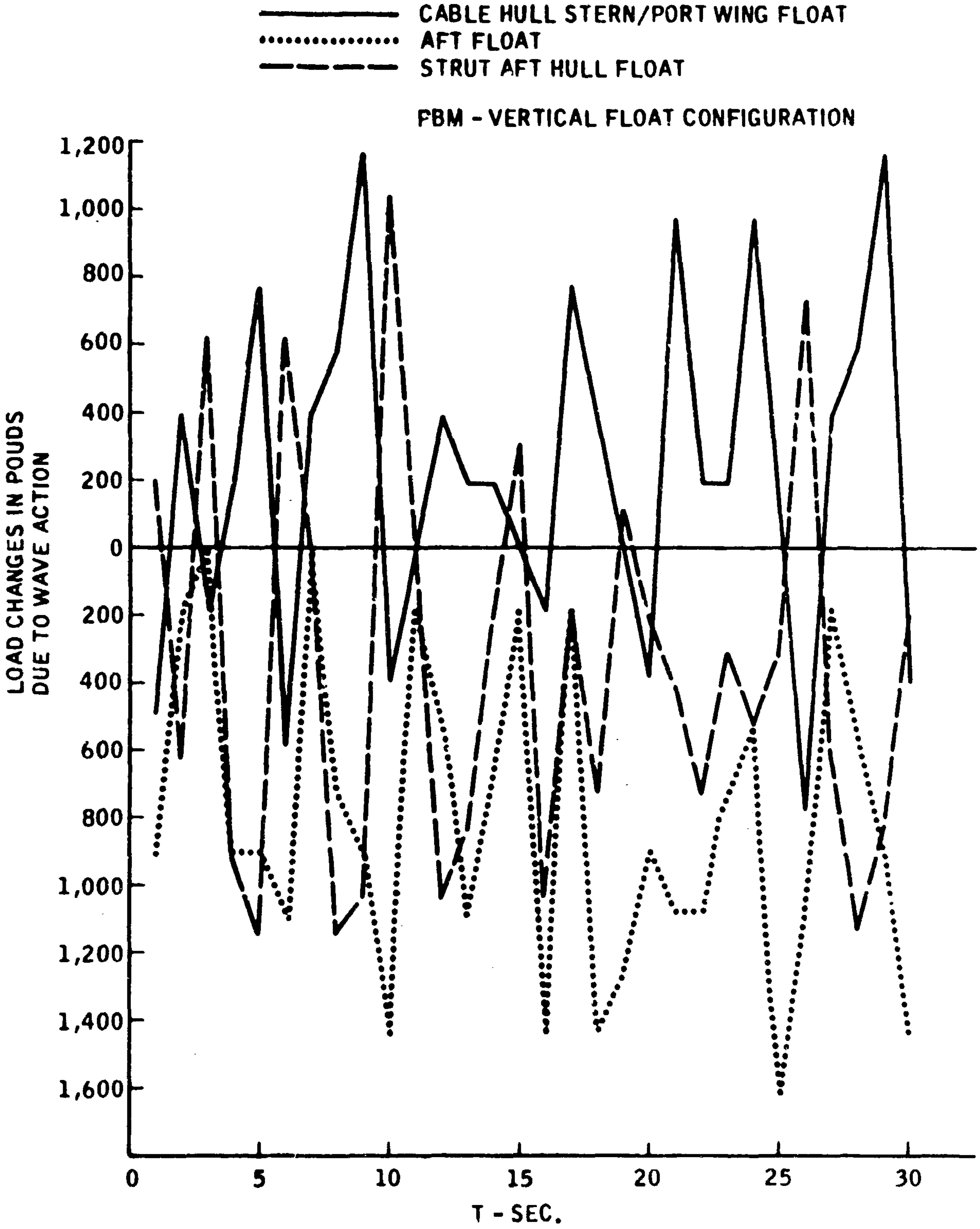


Figure 14D. Variations of Structural Loads Due to Waves

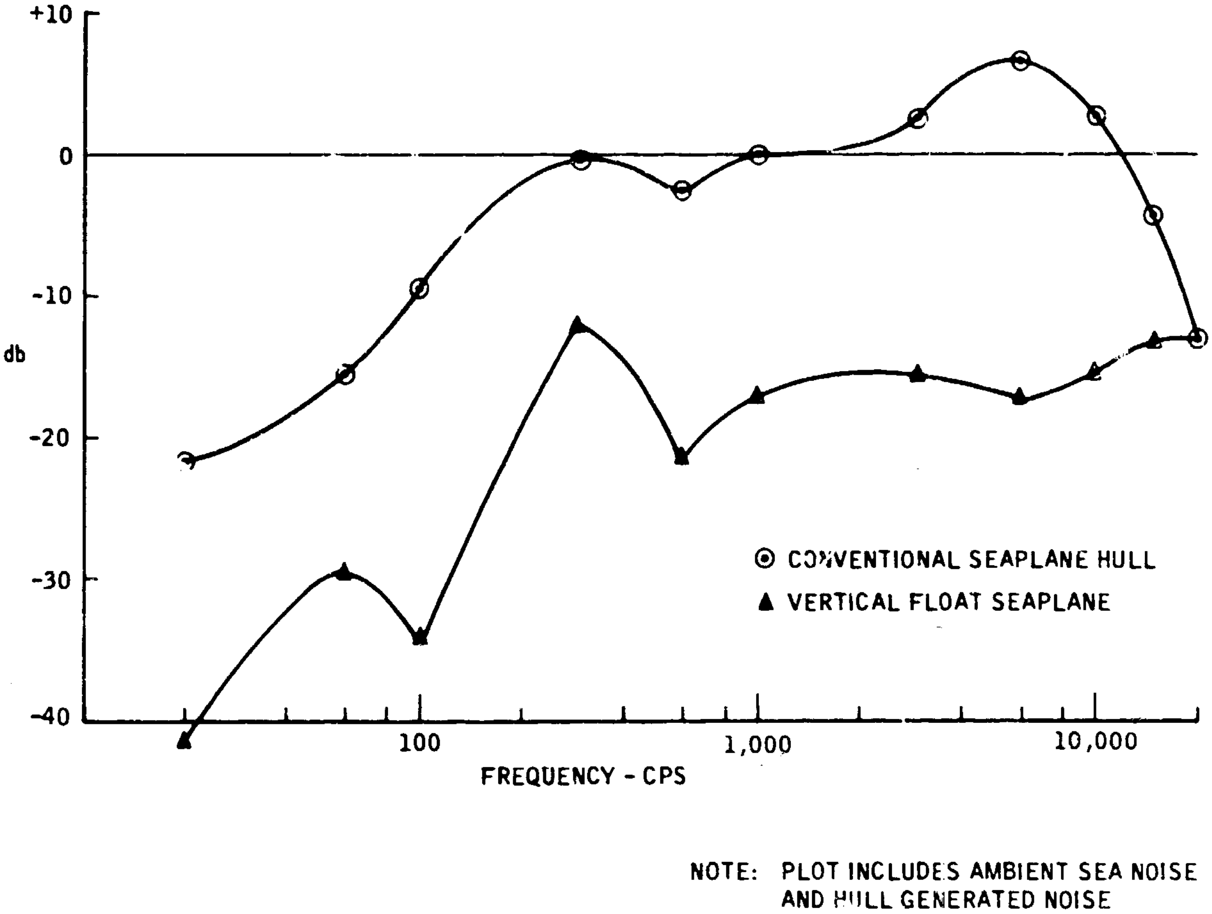


Figure 15. Underwater Noise Comparison

4 | FUTURE DEVELOPMENTS

Based on the success of this exploratory program, further development of the vertical float stabilization system should now be directed toward the perfection of a practical airborne version. Research and development effort is now needed to determine metacentric height, new float geometries, the use of new materials and other aspects to fully exploit the vertical float concept.

Proving the effectiveness of the vertical float concept on the current PBM program offers a solution to the ancient problem of achieving a stable platform at sea. This potential is not limited to aircraft alone, but could be applied to small ships and floating platforms of all sizes. One obvious use of the system would be on a vertical take-off and landing ASW or air sea-rescue seaplane where on-the-surface stability, and extended sea keeping ability are important factors when combined with the inherent speed, range, and load carrying ability of the fixed wing aircraft.

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1. Vine and Volkman, Woods Hole Oceanographic Institute (1950).

2. Symposium on Ship Operation, Part I, How They Perform, Transactions of the Society of Naval Architects and Marine Engineers (1955).

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